581

Some Fibers From the Proteins

Thomas L. McMeekin,
Robert F. Peterson,
Sam R. Hoover

The twentieth century brought a new era in the production of fibers. Chemistry gave us artificial fibers, the rayons, from the cellulose of wood, to supplement such natural fibers as wool, silk, cotton, and flax, which come from animals or plants. Pioneer work started also on making fibers from proteins—vegetable proteins, which are concentrated in the leaves and seeds of plants, and animal proteins, casein, gelatin, hair, and feathers, which are byproducts and are almost entirely protein. Because cellulose is more abundant and cheaper, artificial fibers from wood have had a greater development than fibers from the proteins. Tremendous amounts of proteins are available for industrial use, however.

The first commercial protein fiber was developed from casein by Antonio Ferretti in Italy in 1935. An American factory made a similar commercial staple fiber from casein and sold it under the trade name of Aralac. Between 1940 and 1947, it manufactured 5 million to 10 million pounds of Aralac annually. The factory changed ownership in 1947 and was converted to the manufacture of a fiber from the corn protein, zein, which is sold under the name of Vicara. A large-diameter casein fiber now is produced commercially for use in automobile air filters and as a padding material in furniture.

It is of economic importance to agriculture that industry make use of the proteins from surplus and waste agricultural products in the most efficient way. One way is to make artificial fibers, each according to its particular properties. The properties that make the natural protein fibers, such as wool, so valuable derive from their internal structure. They are made up of flexible chains of amino acids, which are tied together to make a strong and elastic fiber. Cloth woven from them springs back into shape after it is stretched. Strength and elasticity allow blankets to remain thick and warm for many years and permit a good worsted suit to retain its shape, come heat or high water.

The same amino acid chains make up the industrial proteins. It is a challenge to the chemist to arrange them in a fibrous form and thus produce a new and valuable product. Not that he can make a new fiber just like wool or silk; each protein has its own chemical characteristics. What these are, and how they can be used or altered, is a different problem with each protein.

Every new possibility is being studied and tested. The kind and amount of the different amino acids in the chains, the length of the chains, and the chemical reactions by which they can be tied together, all are being measured in the laboratory. The way we do it and the processes for making the fibers are reviewed here.

Casein, the principal protein of milk, is essentially the same as cottage cheese. It is a relatively pure protein and is available commercially in large amounts. Its conversion into fibers offers a means of utilizing skim milk from butter making. The properties and therefore the uses of casein fiber can be varied by the methods of manufacture.

Casein for making fibers must have

a high degree of purity. It should be light in color, easily soluble in alkali, and free from nonprotein materials. The preparation of a suitable spinning solution is the first stage in the production. The casein is dissolved in water that contains about 2 percent by weight of alkali to make a viscous solution with 20 to 25 percent protein. If too much alkali is used, the casein is broken down by the excess alkali and the fiber is inferior.

The next step is to pump the filtered casein solution by a metering pump through a platinum-gold alloy disc, or spinneret, which has thousands of fine, accurately placed, and uniform holes. Each hole is usually 0.004 inch in diameter—that is, 250 of them measure an inch. The solution, streaming from the holes of the spinneret, is immersed in water that contains an acid. The acid neutralizes the alkali used to dissolve the casein. The small, continuous fibers are then stretched, treated in various solutions, and collected by the spinning machinery.

The tensile strength of the yarn is enhanced by stretching the fiber while it is being tanned with aluminum salts and formaldehyde. It is stretched by passing it over rollers, each of which is driven at a higher speed than the preceding one. The action of the hardening baths can be accelerated by heating, and the fiber can then be stretched much more than at low temperatures. The strength of the fiber can be almost doubled by stretching. The standard casein fiber has a dry strength of 16,000 pounds to the square inch and a wet strength of 8,000 pounds. By carrying out the stretching and hardening over a longer period, the dry strength can be raised to 20,000 pounds and the wet strength to 10,000 pounds to the square inch.

A further treatment is needed in order to make the fiber resist the boiling bath commonly used in dyeing wool. Aralac was made resistant to boiling by acetylation with acetic anhydride in naphtha; another promising, inexpensive method involves heating the fiber in the presence of acid and formaldehyde.

Usually the fibers are cut into short lengths and spun in a blend with cotton, wool, or rayon. To the cellulosic fibers the casein fibers impart warmth, crease resistance, and resiliency. Recently we developed a laboratory-scale process for making a continuous-filament all-casein yarn, which has superior resiliency, softness, and dyeing properties. It should have the same type of uses as filament rayon and should be used in woven fabrics.

THE DEVELOPMENT of a domestic source of supply of artificial fiber of the size and properties of horsehair and hog bristle is of strategic importance and economic value because these fibers are largely imported from the Orient and become critical when trade relations are disturbed. About 6 million pounds of pig bristle and 4 million pounds of horsehair are imported annually. It is unlikely that an adequate domestic supply of coarse animal hair can be developed to replace imported hair, because the method of dressing animal hair involves much hand labor. A number of synthetic fibers are available for development to meet the demand for large fibers. Their properties and cost will determine their possibilities in this field.

In our laboratory we have developed a method of making a unique and low-cost casein fiber, or bristle, of the size of pig bristle and horsehair. The method differs in principle from the one described for making the textile fiber from casein. Fibers are made by extruding isoelectric casein, which contains 30 to 40 percent of its weight of water, at a temperature just below the boiling point, through a suitable die into air. After extrusion, the fiber is strengthened and made more durable by stretching and treating with either formaldehyde or benzoquinone. It is then dried on a large drum. Making casein fiber by extrusion differs from the previously described method for making textile fiber from casein in that the casein is not dissolved in alkali and precipitated in the fibrous form by spinning into acid. However, the fibers made by the two methods have similar fundamental properties. The extrusion method for making casein fiber is particularly advantageous in making a thick fiber. It is also simpler and less expensive.

Casein bristle is fairly durable under ordinary conditions. It has good flexibility, resilience, and resistance to abrasives and organic solvents. It is three-fourths as strong as horsehair or hog bristle under ordinary atmospheric conditions. Immersion in water for several hours, however, reduces the strength of casein bristle to one-fourth that of natural bristle.

Commercial production of casein bristle has just begun. It has been found to be particularly useful in the coiled form where its outstanding resilience is utilized. At present it is being used in automobile carburetor filters. Another promising use for the coiled fiber is in padding material for furniture, which offers a large and profitable outlet. The straight fiber may go into paint brushes for use with oil-base paint and into dusting brushes. Stiff cloth made with casein bristle woven with cotton thread has unique properties and is useful as a stiffening material in the clothing industry. It is expected that the uses for casein bristle will multiply as it becomes more available commercially.

A PROMISING woollike fiber is made from peanut protein.

Six steps enter into its manufacture: Shelling the peanuts; flaking the peanut kernels; extracting the oil from the flaked kernels by petroleum hydrocarbons at low temperatures; separating the protein from the solvent-extracted flakes or peanut meal; preparing a protein solution; and extruding the protein solution to form the fiber.

In a typical process, the purified peanut protein is dissolved in a solution of caustic soda to yield a thick, molasseslike mass. Other chemicals are added to effect the desired changes in the protein molecules. Then the solution is filtered to remove all undissolved particles. The solution is comparable to the protein solution formed by the silkworm within its body.

When peanut-protein solutions are extruded into air, they do not coagulate. Consequently, they have to be extruded into some chemical solution that will coagulate the protein. One of the most commonly used solutions contains sulfuric acid and sodium sulfate. After the plasticlike fiber has been formed in the solution, it is withdrawn in a threadlike form, stretched, and reacted with other chemicals, such as sodium chloride and formaldehyde. The fiber may be left in the threadlike form and dried for use, or it may be cut into staple lengths approximating the normal lengths of wool.

Peanut-protein fiber is the color of light cream in its natural state and has a soft handle and warmth, like wool. The fiber can be dyed with wool dyes. It has about 80 percent of the strength of wool. It can be stretched without breaking almost as much as wool.

Woven textile fabrics composed of blends of peanut-protein fiber and rayon or wool are used in suitings, linings for coats, and blankets. Two concerns in the United States have made the fiber in the pilot plant and have begun further work on the production of the fiber.

THOMAS L. MCMEEKIN *is head of the protein division in the Eastern Regional Research Laboratory. He is a graduate of Clemson Agricultural College, Tulane University, and the University of Chicago.*

ROBERT F. PETERSON *is a chemist in the same division. He received his doctorate in chemistry from the University of Maryland.*

SAM R. HOOVER *has done chemical research in the Bureau of Agricultural and Industrial Chemistry since 1931. He received his training in Davis and Elkins College, and George Washington and Georgetown Universities.*